Dynamic Simulation and Analysis of Factors Impacting the Energy Consumption of Residential Buildings

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Abstract: Buildings have a close relationship with climate. There are a lot of important factors that influence building energy consumption such as building shape coefficient, insulation work of building envelope, covered area, and the area ratio of window to wall. The integrated influence result will be different when the building is in different climate zone. This paper studies the variation rule of some aggregative indicators and building energy efficiency rates by simulation and analysis of the same building in different climate zones by eQuest, in order to determine how building energy efficiency works in different climate zones.

1、MODEL BUILDING

Fundamental model

There are sixteen fundamental building models in every climate zone ,separately from one floor to 16 floors with a fifty-meter longth , ten-meter width and 2.8-meter layer hight;all the other parameters of building envelop is in the following table1, indoor environment parameters is as follows,

1) design temperature of air-con operation, 26℃
2) for summer and 18℃ for winter
3) air change times, one per hour
4) EER is 2.2 and COP is 1.9

Ultimate building shape coefficient[1]

The building shape coefficient will decrease and tend to be a boundary value when the building floor raises(floor height is fixed value) with a fixed cross-section, and this boundary value is ultimate building shape coefficient.

The ultimate building shape coefficient of the building with a rectangle cross-section(longth is a and width is b) is as follows,

$$\lim_{n\to\infty}\frac{F_0}{V_0}=\lim_{n\to\infty}\frac{ab+n\cdot 2(a+b)h}{n\cdot abh}=2\left(\frac{1}{a}+\frac{1}{b}\right)$$

n is for building floors

F_0，N_0 is for building surface area and volume individually

1.1 Analysis of simulation results for fundamental models

Analyse three aggregative indicators of building energy efficiency in five climate zones, all-year electricity consumption index for heating, kwh/m^2; all-year electricity consumption index for cooling, kwh/m^2;overall electricity consumption index, kwh/m^2

Tab. 1 main building envelop parameters of fundamental model

title	type	Coefficient of heat transmission
Exterior window	single alum alloy window clear	6.4
Exterior wall	concrete hollow block wall	2.37
roof	120 mm reinforced concrete slab	3.71
floor	120 mm reinforced concrete slab	3.8

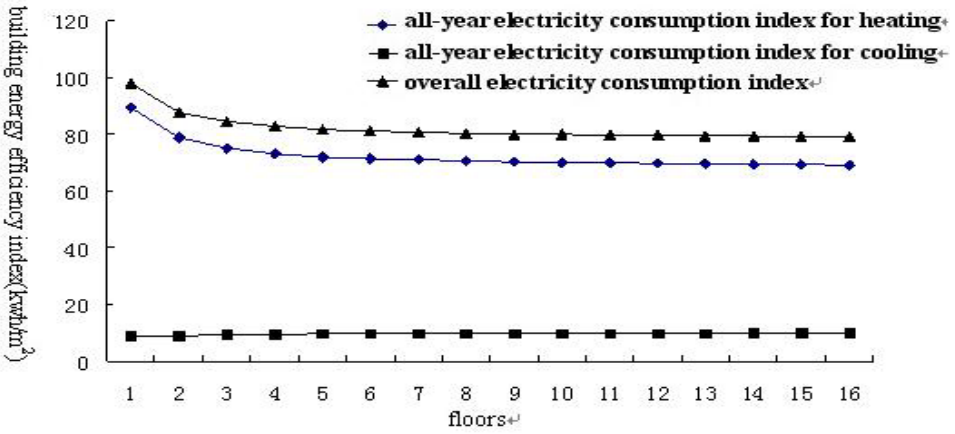


Fig .1 Simulation result of Beijing model

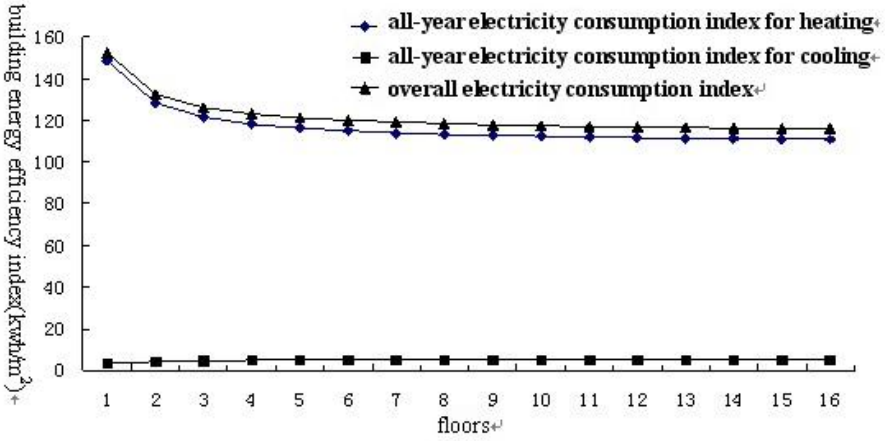


Fig.2 simulation result of Harbin model

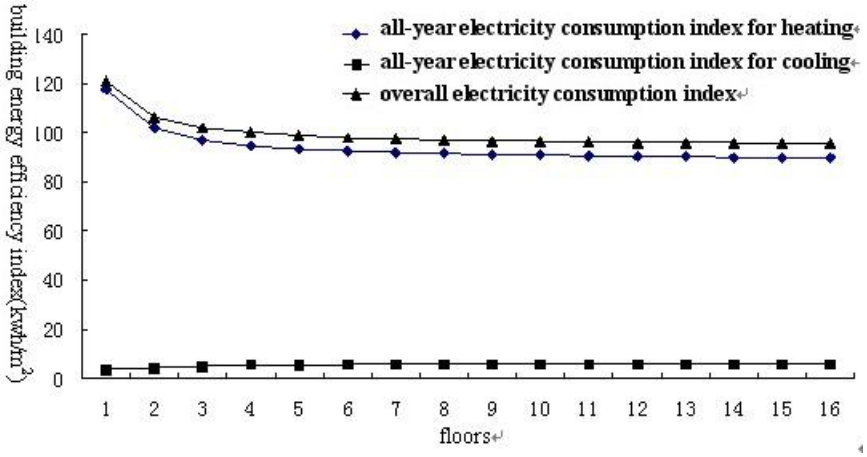


Fig.3 simulation result of Shenyang model

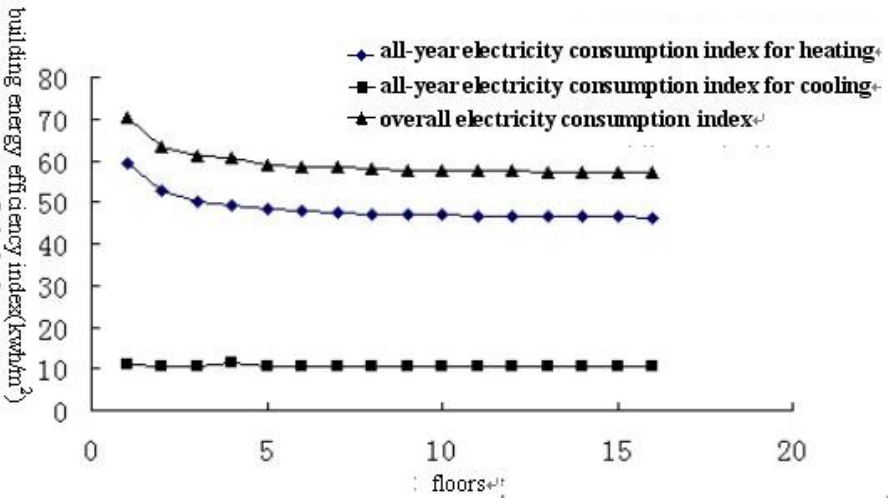


Fig.4 simulation result of Shanghai model

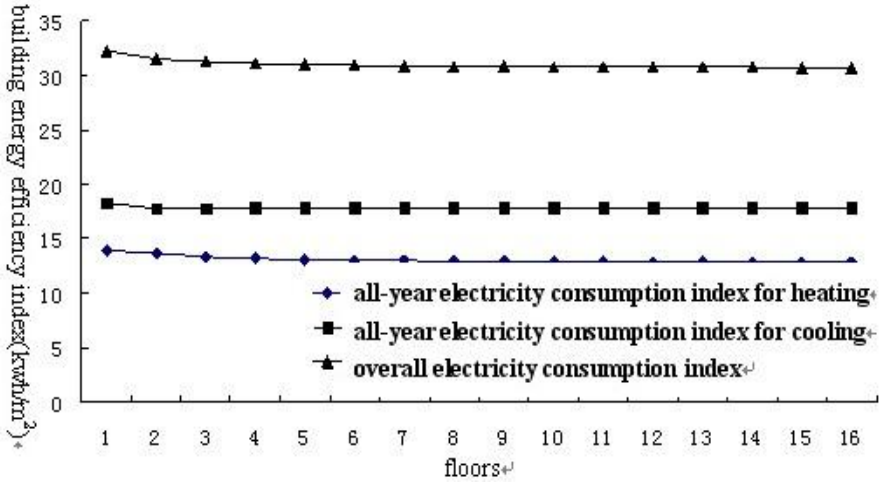


Fig.5 simulation result of Guangzhou model

We can see from all these simulation results that the all-year electricity consumption index for heating and overall electricity consumption index present a decreasing tend to different degree when the fundamental model floors raise on the basis of the analysis of ultimate building shape coefficient, and the all-year electricity consumption index for cooling in Beijing,Haerbin and Shenyang present a increasing tend within a narrow range, but the variation curve of all-year electricity consumption for cooling in Shanghai and Guangzhou is flat with the building shape coefficient's decrease; variation rule of building energy efficiency index in four cities(Beijing,Haerbin,Shenyang,Shanghai)is the same as the variation trend of building shape coefficient when the building floors changes, the decreasing range is large at the beginning 5 to 7floors,and tends to be a flat line on 7to 8floors and the upper floors;the variation curve of three indexes in Guangzhou is flat when the building shape coefficient changes.

Then, it is found that variation rule of every building energy efficiency index of the same building in different climate zone is the same as that of building shape coefficient on the whole; at first, the building energy efficiency index decreases fast and the energy saving effect which is brought by building shape coefficient is obvious, but the variation curve of each index is flat and tends to be a fixed value when the building floors raise further and the building shape coefficient tend te be ultimate building shape coefficient, and the energy saving effect is not significant then.

2、SIMULATE AND ANALYSE MODELS AFTER ADDING SOME BUILDING ENERGY EFFICIENCY MEASURES

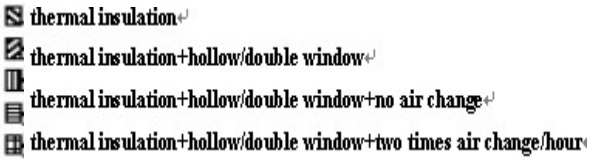
There is no energy efficiency measures which is added to fundamental models,and it will add some energy efficiency measures in four aspects such as the ventalition ways and building envelop and watch the variation rule of energy efficiency rate

Four measures is

1) add thermal insulation
2) add thermal insulation+hollow/double window
3) add thermal insulation+hollow/double window+no air change
4) add thermal insulation+hollow/double window+two times air change/hour

2.1 Analyse simulation results

it combines the four results together and analyses the variation tendency of three energy saving index



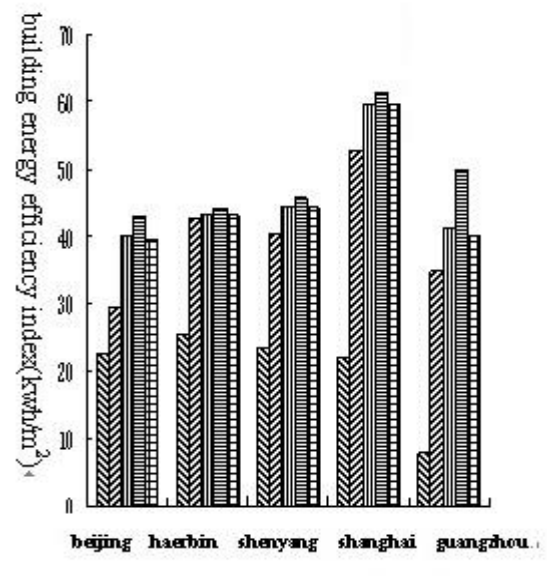


Fig.6 Variation ratio of all-year electricity consumption index for heating

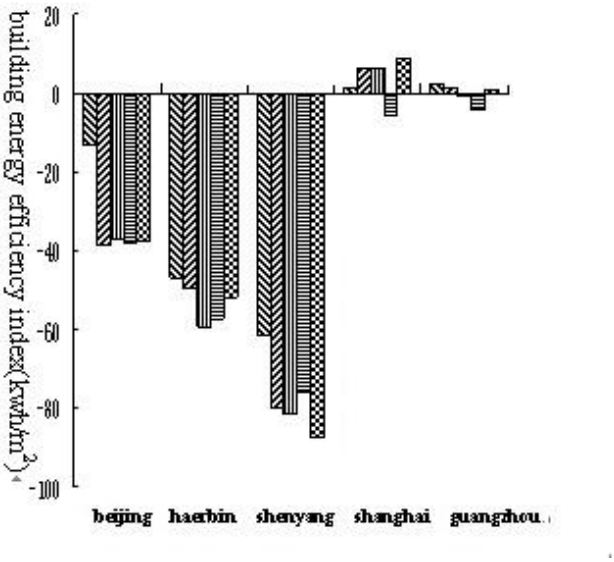


Fig.7 Variation ratio of all-year electricity consumption index for cooling

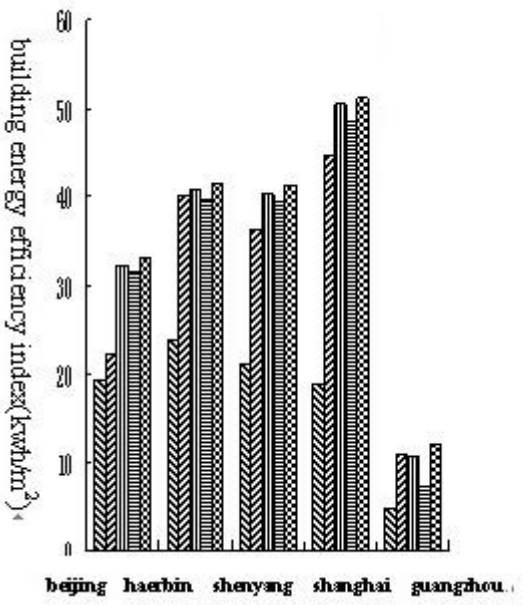


Fig.8 Variation ratio of overall electricity consumption index

To sum up, the energy saving effect is an integrate acting result, it has relationship with climate condition, thermal characteristics of building envelop and ventilation ways etc,and the increasing range of energy saving rate will be different as the energy saving measures is different. Take beijing ,which is representative of the cold zone ,for example, it not only needs heat insulation in the winter but also needs heat pretection in the summer, and the thermal characteristics of exterior windows takes the most important place in the increasing part of energy efficiency rate, so the energy saving effect is not

obvious by adding insulation work on exterior walls only, and it's advisable for us to add insulation on exterior windows at the same time;but the energy saving effect which is brought by insulation on exterior walls is large in the severe cold zone such as Haerbin and Shenyang and the exterior windows takes the small part ;energy saving potential which is brought by the decrease of builidng shape coefficient is the largest in hot summer and cold winter zone such as Shanghai,and the effect is mainly brought by insulation measures added to exterior walls,so it's advisable to strengthen thermal characteristics of building envelop such as exterior walls in these areas;increasing rate of each energy efficiency rate is not obvious in hot summer and warm winter zone such as Guangzhou,and the energy saving effect brought by adding insulation on exterior walls and increasing air change times is relatively obvious.

Moreover, the absolute overall energy consumption variation differs a lot in different climate zones after adding the same energy saving measure to the same building, and it is shown that the climate condition influences the absolute overall energy consumption variation greatly[2];but the relative overall energy consumption variation ratio is approximately the same in different climate zones, that is to say, the climate condition influences the relative overall energy consumption variation ratio very little from macroscopic view, but the significant difference of climate condition(such as daily range,temperature,radiation and humidity)will influence it to some extent[3].

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